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WATER QUALITY STUDIES: ROOSEVELT LAKE -
WASHINGTON

Environmental Health Center
Cincinnati, Ohio

22 May 1953

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WATER QUALITY STUDIES
ROOSEVELT LAKE - WASHINGTON

May 22, 1953

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**U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE**

**Public Health Service
Environmental Health Center
Cincinnati, Ohio**

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COLUMBIA RIVER DISTRICT - COLUMBIA BASIN PROJECT
POWER FIELD DIVISION
COULEE DAM, WASHINGTON

November 9, 1953

Mr. Ralph C. Palange
Acting Assistant Director of Research
Environmental Health Center
1014 Broadway
Cincinnati 2, Ohio

Dear Mr. Palange:

Thank you for sending me the very interesting copy of your report on "Water Quality Studies, Roosevelt Lake - Washington." We are naturally much concerned with this Lake as it is the result of the construction of the Grand Coulee Dam, a Bureau of Reclamation project.

We note that on page 43, line 23 of your report, appears the statement "Results at Range C-597, near Grand Coulee Dam were all less than 45 M.P.N. per 100 milliliters, indicating no seepage through the fill separating Crescent Bay and Roosevelt Lake."

Although samples can be obtained which indicate the accuracy of the above quotation at certain levels of the drawdown of the Lake's surface, we have, nevertheless, obtained samples at various times at certain other levels which definitely establish the existence of leakage through the fill. This is a matter of grave concern to us as the fill was not designed or constructed to act as a dam with such a high head.

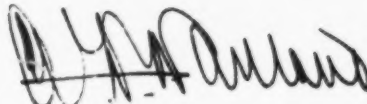
The Washington State Health Department sanitary engineers, the County sanitary engineers, and the Washington State Pollution Control Commission have all expressed anxiety over this condition. Should the Rattlesnake fill break, a large accumulation of sludge and sewage would be drawn into the pumps supplying the Columbia Basin Project and delivered via the canals to the water users. Contamination from this source also has reached the Left Powerhouse at Grand Coulee Dam. It is then delivered by the project water system to all employees

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of the Bureau of Reclamation on duty. In some instances our samples have indicated this does occur, at which times heavy chlorination must be used for protection.

We do not question the accuracy of your statement as of the time you made the tests, as we also obtain pollution-free samples at various times. It is the occasional polluted sample, however, which gives us much concern. We are anxious that the various agencies involved do not become complacent and reassured by your report, as this long-standing hazard to the public health has worried everyone concerned since its beginning. A permanent solution must eventually be found for it.

Very truly yours,

A handwritten signature in dark ink, appearing to read 'A. F. Darland', written in a cursive style.

A. F. Darland
District Power Supervisor

SYLLABUS

A study of the water quality characteristics and biological conditions in Roosevelt Lake was made during the period September 22 to October 1, 1952. Information from this reservoir, a high "multiple purpose" type of impoundment with water depths up to 385 feet, would be expected to give data valuable in predicting effects of future Columbia River impoundments.

Samples of water, plankton, bottom animals and fish were obtained at ten ranges throughout the reservoir to determine existing physical, chemical, bacteriological and biological characteristics. Radiological background information was obtained from some of these samples.

While physical and chemical conditions of the water appear favorable for the support of a mixed aquatic biota, some changes in water quality within the reservoir as a result of the impoundment are indicated. These changes include:

1. An increase in water temperature from the upper to the lower sections of the lake. Little or no thermal stratification was evident at any of the ranges examined.
2. A slight decrease in dissolved oxygen saturation, especially in the deeper waters, although only one area showed a definite oxygen deficiency.
3. An increase in the free CO_2 , with a corresponding change in pH values, from the surface to deeper waters.
4. A possible increase in manganese and iron in the deeper waters.
5. A decrease in the suspended materials load from the upper to the lower reservoir.

Bacterial contamination in most parts of the reservoir was at a minimum, although M.P.N. values of 700 per 100 ml. and over were found in the upper part.

Biological conditions were in general very poor. Phytoplankton was extremely limited throughout the reservoir but a buildup of zooplankton was quite noticeable in the lower half. The bottom fauna was quite sparse,

consisting only of a few tolerant species, and much different from unimpounded sections of the Columbia River. The large amount of suspended material in the Pend Oreille River appeared detrimental to bottom fauna in and near its mouth. Fish were also limited, the principal population being rough and forage species, with few game fish and little sport fishing.

The low biological productivity is thought to be due principally to:

1. The lack of nutrient materials in the inflow waters which drain infertile mountain regions.
2. The annual deposition of suspended material, especially in the upper reaches of the reservoir.
3. The high ratio of incoming water to reservoir capacity, causing frequent replacement of the contents.
4. The sharp drop-off at the shore line, giving very few areas of shallow water.
5. The large winter and spring drawdowns, which limit aquatic vegetation and bottom fauna production and may affect fish reproduction.

Radioactivity values were all at or near instrument background.

Other studies made in April 1953, at maximum drawdown levels, indicated:

1. Little change in physical and chemical conditions and no appreciable quantities of heavy metals believed to be toxic.
2. Penetration of finely suspended rock flour for a considerable extent into Roosevelt Lake. Much of this turbidity reportedly originates at various base metal recovery mills on the Upper Columbia, Pend Oreille, and Salmo Rivers.
3. A heavy pulse of the diatom Asterionella sp in the lower reservoir.
4. No bacterial contamination into the lower lake through the earth fill separating Crescent Bay.

GENERAL INFORMATION

The main objective of the Roosevelt Lake studies was to obtain water quality characteristics and biological data on an existing Columbia River impoundment. The data thus obtained will assist in predicting the effects of future impoundments on this stream.

Since Roosevelt Lake is a high, "multiple-purpose" type of impoundment the data would indicate one extreme of conditions to be expected in future impoundments. The information from the Bonneville area, a low "run-of-the-river" impoundment, indicates the other extreme of conditions to be expected. All other proposed reservoir projects, at least on the main river, would fall somewhere between these extremes. Several agencies were interested in various phases of this work and the data obtained will be useful to them.

PARTICIPATING AGENCIES

Other agencies participating in the survey were the Washington State Department of Health, Washington State Pollution Control Commission, the U.S. Bureau of Reclamation, U.S. National Park Service, and the Pacific Northwest Drainage Basins Office of the Public Health Service.

The State Department of Health is primarily interested in the sanitary quality of the stream as it may relate to bathing beach and picnic area water quality as well as to water usage by municipalities in the area.

The State Pollution Control Commission and the Pacific Northwest Drainage

Basins Office of the Public Health Service are interested from the standpoint of their overall State and Federal pollution control responsibilities. The Bureau of Reclamation is interested in the sanitary quality of the waters from the standpoint of usage by municipalities, both in the reservoir area and at downstream points.

The National Park Service, having jurisdiction over the lake and immediate shore areas for recreational purposes, is interested in sanitary water quality as it may affect bathing beaches and picnic areas, as well as ecological conditions as they may relate to other recreational possibilities such as fishing or hunting.

GENERAL PLAN OF OPERATION

The survey was conducted during the period September 22 to October 1, 1952. Low water stages and maximum water temperatures are normally expected at this season of the year.

Ten sampling ranges were established within the reservoir area. Each one was designated by a mileage index number, which gives the distance in miles from a fixed reference point established by the U.S. Corps of Engineers at the mouth of the Columbia River. The use of this system permits a direct tie-in with studies made in other sections of the Columbia River. Sampling ranges were located from the standpoint of obtaining information on the reservoir as a whole as well as on particular areas of interest to other agencies. Time was not available for a study of individual sources of pollution.

The area covered by the study and the location of sampling ranges are shown in figure 1. Sampling ranges were established as follows:

CPO-756: Pend Oreille River, approximately 10 miles above the mouth.

This was the first easily accessible point above the

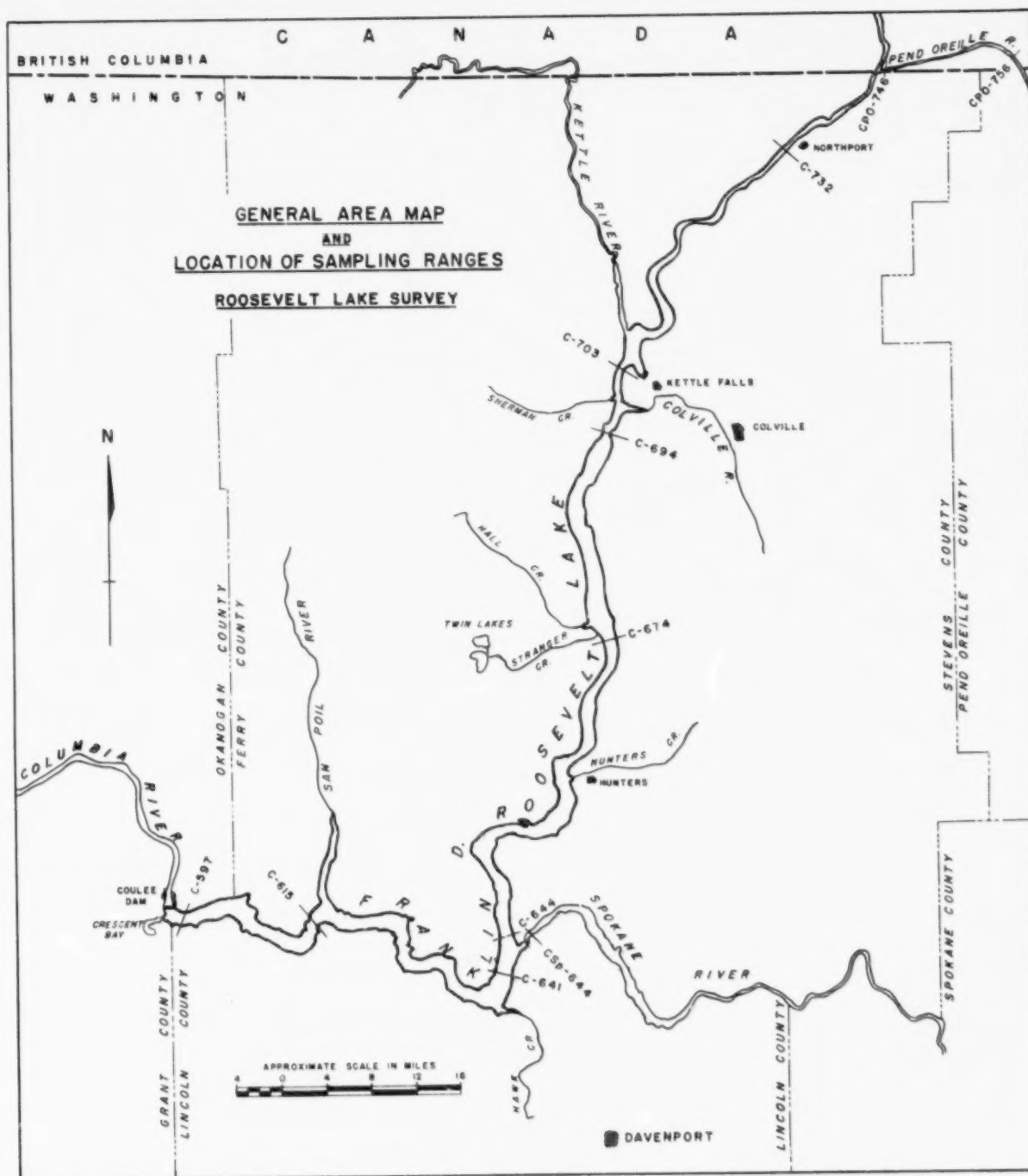


Figure 1

Consolidated Mining Company's dam, under construction near the mouth of the river. It was expected that the construction would have some effect on the downstream water quality and hence samples below that point would not indicate the natural water quality characteristics of this tributary.

CPO-746: Immediately above the mouth of the Pend Oreille River and below the Consolidated Mining Company's dam. This stream enters the Columbia River above the backwater from Roosevelt Lake and is quite rapid and turbulent at this point.

C-732: At old ferry landing, near center of Northport, Washington. The river current here is quite rapid and not noticeably affected by backwater. All stations below this were well within the backwater areas and there was no noticeable current.

C-703: South of U.S. Highway No. 395 Bridge near Kettle Falls, approximately two miles below the mouth of the Kettle River.

C-694: Two miles below the mouth of the Colville River, near Rickey Point Light.

C-674: Below Gifford Ferry.

C-644: One mile above the mouth of the Spokane River.

CSp-644: Spokane River, one mile above the mouth and just above State Highway No. 22 Bridge. This range is within the backwater area.

C-641: Two miles below the mouth of the Spokane River.

C-615: One mile below the mouth of the San Poil River, just west of Republic Ferry. A National Park Service boat ramp and possible swimming area are located on the south shore at this section.

C-597: One mile above Grand Coulee Dam. A National Park Service swimming area and boat ramp are located on the North Shore.

Crescent Bay: A bacteriological sampling point was established near the junction of Crescent Bay with Roosevelt Lake. An earth fill separates these two bodies of water. The untreated domestic sewage from the town of Grand Coulee empties into Crescent Bay and some seepage into the lake was suspected. Since water is pumped from the reservoir a short distance below this dike, the Bureau of Reclamation was quite interested in obtaining bacteriological analyses of the reservoir water in this vicinity.

Space for field laboratories was made available by the National Park Service at their Coulee Dam Ranger Station on the north shore, near Range C-597, and at their Kettle Falls Ranger Station, on the east shore between Ranges C-703 and C-694. Simple chemical and biological examinations were performed at these field laboratories. Other more complex determinations, such as mineral analyses, were made in the Public Health Service laboratory at Richland, Washington. Bacteriological analyses were made by the Bureau of Reclamation laboratories in Ephrata, Washington, as well as by personnel of the Washington State Health Department and Pollution Control Commission at the City Health Department laboratories in Spokane.

Personnel assigned to the field study included two biologists and one chemist from the Columbia River Studies Group, and one biologist from the PHS Pacific Northwest Drainage Basins Office for most of the survey. Other personnel from the Columbia River Studies group picked up samples for return to the Richland laboratory. Personnel from the Washington State Health Department transferred the bacteriological samples from the point of collection to the laboratory.

Samples were collected from two portable aluminum boats equipped with outboard motors, the units being transported overland to the various ranges. During the period when one of the motors was inoperative the National Park Service furnished a power launch for collecting some of the samples. Personnel from that agency also assisted materially in locating ranges.

DESCRIPTION OF ROOSEVELT LAKE AND SURROUNDING AREAS

Franklin Delano Roosevelt Lake, the reservoir formed by impoundment of the Columbia River behind Grand Coulee Dam, extends from the Dam to near the Canadian border, a distance of about 150 miles. The lake averages about a mile in width, is over 350 feet at maximum depth, and covers an area of approximately 85,000 acres. There are six hundred miles of shoreline around the reservoir and, when full, it holds nearly 10 million acre-feet of water.

Measured reservoir depths varied from a maximum of about 40 feet, at Range C-732, to a maximum of about 385 feet at Range C-597, near Grand Coulee Dam. The gradient of the lake bottom was gradual between Range C-732 and Range C-597. Maximum recorded depths at the various ranges were as follows:

<u>Range</u>	<u>Depth in Feet</u>
C-732	40
C-703	150
C-694	150
C-674	200
C-644	220
CSp-644	170
C-641	270
C-615	340
C-597	385

Grand Coulee Dam, largest concrete structure in the world, is located at river mileage 596.5, in the northeast part of Washington, 92 miles west and North of Spokane and 240 miles east of Seattle, by highway. This dam, part of a so-called "multiple purpose" project, was built by the Bureau of

Reclamation and completed in 1939. It is designed to ultimately irrigate one million acres of semi-arid land in the Columbia Basin and to develop 2-1/2 million kilowatts of electrical power. Some storage capacity is available for flood control purposes.

The area surrounding the lake is sparsely populated, the towns of Grand Coulee, Coulee Dam, Davenport, Colville, Kettle Falls, and Northport being the main centers of population. The extreme lower twenty miles of the reservoir is in semi-arid territory having grasslands and sagebrush cover. The remainder is sparsely to densely forested. The area on the west side of the Lake is relatively inaccessible and is occupied mainly by the Colville Indian Reservation and the Colville National Forest. Wheat farming, live-stock grazing and lumbering are the principal operations on the east side of the lake. Some mining operations are also carried out. The National Park Service has control of the reservoir and the immediate shoreline areas for development of recreational facilities. Good highways provide relatively easy access to the east side of the lake.

A large portion of the waters come from snows in remote, high mountain regions in Canada, Eastern Washington, Idaho and Western Montana. No provision is made at Grand Coulee Dam for either fish passageways or navigation locks as the height of the structure, 370 feet, precludes its use for these purposes under present knowledge and conditions.

STREAM FLOWS

River flows were low and quite uniform during the survey, the reservoir being about five feet below the normal pool elevation of 1,290 feet above mean sea level. The flows at this time were probably approaching the minimum low values of approximately 25,000 c.f.s. which generally occur in the late fall and winter. The storage capacity of the reservoir is drawn upon during

these low flow periods and the reservoir may be drawn down to a maximum of 80 feet before the annual spring run-off period usually occurring in May or June. The normal pool elevation is maintained at all times except during periods of drawdown. Spillways are designed for a maximum capacity of 1,000,000 c.f.s. During high run-off periods surplus water is also pumped into the equalizing basin for irrigation.

Normal flows during the summer are generally adequate for both irrigation and power purposes and there is little change in lake elevation during the summer months. Average annual run-off into the reservoir is just under 80,000,000 acre-feet. The mean annual discharge at the dam is approximately 104,000 c.f.s, with a maximum recorded flow of 638,000 c.f.s. occurring in June 1948.

During the period of this survey, surface velocities in the reservoir were negligible. The only location within the impoundment having any noticeable velocity was at Range C-732.

SURVEY PROCEDURES

Samples of water and aquatic organisms were collected at all ranges and at various depths for the determination of physical, chemical, bacteriological and biological conditions. Later, some of the samples of plankton, juvenile fish and adult fish which had been collected and preserved were examined for alpha and gross beta radioactivity densities. The procedures used for the collection and examination of these samples are described briefly in this section.

Physical and chemical determinations on individual samples included those for temperature, turbidity, dissolved oxygen, alkalinity, pH and free carbon dioxide. Analyses for calcium, magnesium, iron, manganese, zinc, copper, nitrates, sulfates, phosphates, specific conductivity and total solids were made on composite samples.

Biological determinations covered the quantitative estimation of plankton and bottom animal populations and studies of juvenile and adult fish. Bacteriological examinations were limited to determination of the M.P.N. Coliform Index.

COLLECTION OF SAMPLES

The collection of various samples was in accordance with procedures used or adapted for the Public Health Service studies in the Priest Rapids - Paterson section of the Columbia River. Some modifications were necessary because of the greater water depths.

Water

Samples of water for field determinations of temperature, turbidity, dissolved oxygen, alkalinity, pH and free carbon dioxide were taken with either a 1 - or 3-liter Kemmerer sampler at various depths, between the surface and the bottom. Collections were made at quarter points across all

of the ranges. Five-gallon composite surface samples were taken at all sections, as well as in deep water near the reservoir bottom at Ranges C-694, C-641, and C-597, for mineral determinations.

Samples for bacteriological examinations were collected near each shore and at quarter points at all ranges. These were taken by filling sterile bottles held immediately below the water surface.

Aquatic Organisms

Composite water samples from the surface and near the bottom were obtained at most of the ranges for quantitative plankton determinations. Other plankton samples were collected from tows made with a standard number 20, silk bolting cloth net (173 meshes per inch) in order to determine the presence and relative abundance of some of the larger plankton organisms, mostly zoo-plankton.

Quantitative bottom animal collections were made with a 1/4-square foot Ekman dredge at all ranges, between 2 and 6 samples being taken at each section. A few shallow bottom areas at various shore points were examined to determine the presence and relative abundance of bottom animals.

Juvenile fish were taken near shore areas by seining with a 10-foot 1/4-inch mesh minnow seine. Adult fish collections were taken with gill nets. Overnight bottom sets were made at various depths with 1", 2" and 3" mesh nets. Other information on fish was obtained from the National Park Service, local fishermen and others within the area, as well as from previously published reports.

LABORATORY METHODS

The laboratory methods used for many of the routine examinations were taken from various standard sources. Other procedures were those developed for the studies in the Priest Rapids - Paterson section.

Chemical and Physical Examinations

Analytical techniques used for most of the chemical and physical examinations were those given in "Standard Methods for the Examination of Water and Sewage" 9th Edition, American Public Health Association, with some modifications to fit field conditions.

Surface water temperatures were read from a regular Centigrade thermometer. It had been planned to take depth temperature readings with a Foxboro Portable Electric Thermometer or a Negretti-Zambra reversing thermometer. However, both of these instruments were found to be inoperative and could not be repaired in time for the survey. Consequently depth temperatures were taken immediately on water samples brought up from various depths with the 3-liter Kemmerer sampler. It was felt that readings would be quite accurate, as the time involved in taking samples was very short. The temperature differential from surface to bottom is generally small, as indicated by Bureau of Reclamation and Fish and Wildlife Service data.

Surface turbidity readings were made where possible with a USGS Standard Water Turbidity Scale. Analyses for dissolved oxygen, free CO₂, pH and alkalinity were done in the field with a portable chemical kit. The pH values were determined with a Hellige¹ colorimetric comparator disk. All other chemical determinations were made at the Richland laboratory.

Methods for the determination of copper and zinc were taken from "Colorimetric Determination of Traces of Metals", by E. P. Sandell (Interscience Publishers Inc., 1950). Specific conductances were determined with an Industrial Instrument Company Solu Bridge, Model RD-R-4.

Bacteriological Examinations

Examinations of bacteriological samples were made by other agencies, previously mentioned. These tests were confined to the determination of the M.P.N. Coliform Index as outlined in "Standard Methods, IX".

Biological Examinations

Procedures for the collection and examination of aquatic organisms generally followed those given in "Limnological Methods", by P. S. Welch (The Blakiston Company, 1948).

For plankton determinations six-liter water samples for count and 10-liter samples for weight were centrifuged in a Foerst Centrifuge set up at the temporary field laboratory. The organisms were removed and preserved in 10% formalin for future study. Later, in the Richland laboratory, these were identified and numerical counts made in a Sedgewick-Rafter counting cell. Weights were determined after drying at 60°C for 24 hours. Organic content was found by ashing in a muffle furnace at 600°C for 30 minutes.

Most of the organisms found were of the single-cell type. However, whether a cell, colony, or filament each individual organism was counted. Most of the colonies of diatoms were broken into individual cells by centrifuging. In general, the Asterionella sp remained intact and several cells were present in each organism.

Bottom organism samples were sorted, identified to order, counted and weighed after blotting for 1 minute to remove surface moisture. Juvenile fish were sorted, identified and relative abundance of the various species noted. Data recorded for adult fish included the length, weight and species of each specimen caught.

Radiological Examinations

It had not been planned originally to obtain radiological data in the Roosevelt Lake study. This lake was above known possible sources of radioactive effluent discharges and it was felt that the only data that could be obtained here would be at background activity levels, near or below minimum detectable limits. Later it was decided to obtain data on biological

samples which had been collected and preserved during the study.

Samples of plankton, juvenile fish and individual parts of adult fish were prepared by digesting in nitric acid, ashing and plating the residue on 1" stainless steel planchets. Gross beta activity densities were determined by counting in a Geiger-Mueller End-Window tube counter and applying necessary correction factors. Some of these samples were also analyzed by another method developed at the Environmental Health Center Laboratories at Cincinnati, Ohio, and counted in internal flow counters for alpha and gross beta activity densities.

DISCUSSION OF RESULTS

The total number of samples collected and analyses made are given in table 1. The results of the laboratory examinations are discussed below.

Table 1 - SUMMARY OF SAMPLING AND LABORATORY LOAD

Examination	No. of Samples	Determinations
Bacteriological	50	50
Chemical and Physical		
Routine	127	912
Mineral Analyses	13	143
Biological		
Bottom Organisms	14	14
Plankton	17	17
Radiological		
Biological	52	79

BACTERIOLOGICAL EXAMINATIONS

Results of the bacteriological analyses are presented in table 2. The M.P.N. Coliform Index was quite low for most of the samples examined. This indicates water relatively free of domestic pollution throughout the reservoir area. The low counts found in the lake near the Crescent Bay entrance show that during this survey there was little or no penetration of domestic pollution through the earth fill separating this area. Results in the vicinity of the National Park Service recreational areas at Ranges C-597, C-615, CSp-644 and C-703 were all uniformly quite low. The highest values within the lake occurred at Range C-732, maximum M.P.N. values of 700, or over, per 100 milliliters being found near both shores there.

Table 2 - RESULTS OF BACTERIOLOGICAL ANALYSES

Sampling Range	Distance from South or East Shore	Date (1952)	MPN per 100 ml.	Sampling Range	Distance from South or East Shore	Date (1952)	MPN per 100 ml.
CPO-746	N. Shore	9/29	240 62	C-644	100'	9/24	<45
					1/4		<45
					1/2		<45
	S. Shore		240		3/4		60
					W. Shore		<45
C-732	100'	9/29	700	CSp-644	100'	9/24	<45
	1/4		130		1/2		<45
	1/2		130		N. Shore		60
	3/4		240				
	W. Shore		> 700	C-641	100'	9/24	<45
					1/4		46
C-703	100'	9/26	60		1/2		<45
	1/4		<45		3/4		<45
	1/2		<45		W. Shore		<45
	3/4		60				
	W. Shore		<45	C-615	100'	9/23	<45
					1/4		<45
C-694	100'	9/26	<45		1/2		<45
	1/4		<45		3/4		60
	1/2		<45		N. Shore		<45
	3/4		<45				
	W. Shore		60	C-597	100'	9/23	<45
					1/4		<45
C-674	100'	9/26	<45		1/2		<45
	1/4		<45		3/4		<45
	1/2		<45		N. Shore		<45
	3/4		<45				
	W. Shore		<45	Crescent Bay	N. End-Dike	9/23	<45
					Mid-Dike		<45
					S. End-Dike		<45

This indicates some domestic pollution in the vicinity of Northport or further upstream. Values in the Pend Oreille River were also higher than in the major portion of Roosevelt Lake proper.

While the values appear uniformly low at this season, additional samples should be taken in the summer months, during periods of maximum recreational use of the lake, in order to obtain a better evaluation from this standpoint. Samples should also be taken adjacent to Crescent Bay during periods of maximum drawdown in order to detect any possible seepage.

PHYSICAL AND CHEMICAL EXAMINATIONS

Results of physical and chemical determinations are given in tables 3 and 4. The individual results are discussed below.

Turbidity

Turbidity readings at all locations within the lake were less than 7 p.p.m., the minimum value detectable with the USGS turbidity scale. Water in the middle and lower reservoir appeared extremely clear and colorless, bottom areas being visible in depths of about 15 feet. The upper lake, Range C-732, was also clear, though some suspended material could be observed. The mouth of the Spokane River was clear but with a greenish cast, most probably due to the presence of plankton algae. All of the smaller tributaries examined were also quite clear.

The Pend Oreille River on the other hand was quite turbid and gray in color. Large quantities of a material resembling rock powder were suspended in the water. The bottom areas and rocks were completely covered with a flour-like gray blanket. The junction of this stream with the clear waters of the Columbia River was quite marked, and the line of demarkation could be followed visibly for a considerable distance downstream. When this condition was first noted at the mouth of this tributary it appeared to be due to the

Table 3 - SUMMARY OF ANALYTICAL RESULTS

Sampling Range	Dist. from South or E. Shore	Depth Ft.	Date (1952)	Turb ppm	Temp °C	D.O. ppm	Free CO ₂ ppm	pH	Alkalinity ppm	
									M.O.	Phen
CPO-760	N. Shore	1	9/29	19	17.0	8.6	0	7.9	80	0
CPO-746	N. Shore	1	9/29	19	17.5	8.8	0	7.9	80	0
C-732	1/4	1	9/29	≤7	16.5	8.4	0	7.6	58	0
		10			16.5	8.4	0	7.6	60	0
		25			16.5	8.3	0	7.5	60	0
	1/2	1	9/29	≤7	16.5	8.4	0	7.7	60	0
		10			16.5	8.4	0	7.7	60	0
		25			16.5	8.4	0	7.7	60	0
		30			16.0	8.4	0	7.7	60	0
	3/4	1	9/29	≤7	16.5	8.4	0	7.7	60	0
		10			16.5	8.4	0	7.7	60	0
		25			16.5	8.4	0	7.7	60	0
		30			16.5	8.4	0	7.7	60	0
		40			16.0	8.4	0	7.7	60	0
C-703	1/4	1	9/27	≤7	17.0	8.2	0.5	7.8	61	0
		10			17.0	8.2	0.5	7.6	60	0
		25			17.0	8.0	0.5	7.6	60	0
		50			17.0	8.0	0.5	7.6	60	0
		100			17.0	8.0	1.0	7.6	61	0
		150			17.0	8.1	1.0	7.6	62	0
	1/2	1	9/27	≤7	17.0	8.2	1.0	7.7	62	0
		50			17.0	8.1	1.0	7.6	61	0
		125			17.0	8.2	1.0	7.6	62	0
	3/4	1	9/27	≤7	17.0	8.3	1.0	7.7	63	0
		25			17.0	8.2	1.0	7.7	62	0
		50			17.0	8.2	1.0	7.6	63	0
		100			17.0	8.0	1.0	7.6	61	0
		150			17.0	8.1	1.0	7.6	61	0
C-694	1/4	1	9/26	≤7	18.0	8.2	0	8.2	65	0
		10			18.0	8.2	0	8.2	62	0
		25			18.0	8.2	0	8.2	62	0
		50			18.0	8.1	1.0	8.1	60	0
		100			17.5	8.0	1.0	7.9	62	0
		150			17.0	7.5	1.0	7.9	61	0
	1/2	1	9/26	≤7	18.0	8.2	0	8.1	62	0
		10			17.5	8.3	0.5	7.9	61	0
		25			17.0	8.2	0.5	7.9	61	0

Table 3 - SUMMARY OF ANALYTICAL RESULTS (Continued)

Sampling Range	Dist. From South or E. Shore	Depth Ft.	Date (1952)	Turb ppm	Temp. °C	D.O. ppm	Free CO ₂ ppm	pH	Alkalinity ppm	
									M.O.	Phen
C-694 (Cont.)	1/2	50	9/26		17.5	8.2	0	7.9	63	0
		100			17.0	8.0	0.5	7.9	62	0
		150			17.0	7.4	1.0	7.7	62	0
	3/4	1	9/26	<7	17.5	8.2	0.5	8.1	62	0
		25			17.5	8.2	0.5	8.1	62	0
		50			17.5	8.1	0.5	8.0	61	0
		100			17.0	8.0	0.5	7.9	60	0
C-674	1/4	1	9/28	<7	18.0	8.3	0	8.2	59	0
		10			18.0	8.3	0	8.2	57	0
		50			17.5	8.1	0	8.0	57	0
	1/2	1	9/28	<7	18.0	8.4	0	8.2	59	0
		50			17.5	8.3	0	8.0	57	0
		100			17.0	8.0	0.5	7.8	58	0
		200			17.0	7.7	1.0	7.7	58	0
	3/4	1	9/28	<7	18.0	8.3	0	8.2	60	0
		50			17.5	8.2	0.5	8.0	58	0
		130			17.0	8.0	0.5	7.8	58	0
C-644	1/4	1	9/28	<7	19.0	8.7	0	8.0	55	0
		100			18.0	8.3	1.5	7.4	60	0
		200			17.5	8.3	2.0	7.4	65	0
	1/2	1	9/28	<7	19.0	8.7	0	8.0	58	0
		10			19.0	8.6	0	8.0	58	0
		25			19.0	8.5	0	8.1	58	0
		50			18.5	8.3	0	8.0	59	0
		100			18.5	8.0	1.0	7.9	-	0
		200			17.5	8.0	1.5	7.8	58	0
	3/4	1	9/28	<7	19.0	8.5	0	8.0	58	0
		50			18.5	8.4	0	8.0	58	0
CSp-644	1/2	1	9/30	<7	19.0	8.4	0	8.0	58	0
		10			19.0	8.1	0	7.9	58	0
		25			19.0	8.0	0	8.0	57	0
		50			19.0	8.0	1.0	7.9	55	0
		100			18.5	5.4	3.5	7.3	65	0
		150			18.0	3.1	6.0	7.2	85	0
C-641	1/4	1	9/24	<7	19.8	8.0	0	-	58	0
		50			18.5	7.9	0	-	58	0

Table 3 - SUMMARY OF ANALYTICAL RESULTS (Continued)

Sampling Range	Dist. From South or E. Shore	Depth Ft.	Date (1952)	Turb ppm	Temp °C	D.O. ppm	Free CO ₂ ppm	pH	Alkalinity ppm	
									M.O.	Phen
C-641 (Cont.)	1/4	100	9/24		18.0	7.5	1.0	-	62	0
		150			18.0	7.4	1.0	-	59	0
	1/2	1	9/24	<7	19.8	8.0	0	-	58	0
		10			19.3	8.0	0	-	57	0
		25			19.3	8.0	0	-	59	0
		50			19.0	8.0	0	-	59	0
		100			18.5	7.6	0.5	-	58	0
		200			18.0	7.4	1.0	-	59	0
		250			18.0	7.0	1.5	-	60	0
	3/4	1	9/24	<7	19.8	8.0	0	-	60	0
		50			19.0	7.9	0	-	59	0
C-615	1/4	1	9/23	<7	19.5	7.3	0	-	59	0
		100			19.0	7.2	0.5	-	57	0
		165			18.5	7.2	1.5	-	57	0
	1/2	1	9/23	<7	19.3	8.2	0	-	59	0
		10			19.0	8.0	0	-	60	0
		25			19.0	8.3	0	-	63	0
		50			19.0	7.9	0	-	65	0
		100			19.0	8.1	0	-	57	0
		200			18.0	7.5	1.0	-	58	0
	3/4	1	9/23	<7	19.3	8.1	0	-	58	0
		10			19.0	8.1	0	-	59	0
		25			19.0	8.2	0	-	59	0
		50			19.0	8.2	0	-	59	0
		100			18.5	7.3	0.5	-	58	0
		200			18.0	7.4	1.0	-	58	0
		340			18.0	6.7	2.0	-	58	0
C-597	1/4	1	9/25	<7	20.0	7.9	0	8.2	60	0
		10			20.0	8.0	0	8.2	60	0
		25			20.0	8.0	0	8.2	60	0
		50			19.5	8.0	0	8.2	59	0
		100			19.0	8.0	0	8.2	59	0
		200			19.0	7.3	2.0	7.8	60	0
		350			18.0	6.3	4.0	7.4	58	0
	1/2	1	9/23	<7	20.0	7.9	0	8.2	60	0
		50			19.8	8.0	0	8.2	60	0
		100			19.5	8.0	0	8.3	59	0
		200			19.0	7.2	2.0	7.6	58	0
	3/4	1	9/25	<7	20.0	7.9	0	8.2	59	0
		100			19.5	7.9	0	8.4	59	2
		150			19.0	7.3	0.5	7.8	59	0

Table 4 - RESULTS OF MINERAL ANALYSES ON RIVER WATER SAMPLES

Sampling Range	Depth (Feet)	Date (1952)	Ca	Mg	Fe	Mn	Zn	Cu	SO ₄	PO ₄	NO ₃	Total Solids	Spec. Cond. /umhos per cm
Concentration - Parts per milligr.													
CFO-760	1	9/30	26	8.0	0.19	0.025	0	0.100	14	0.04	0.08	150	160
C-732	1	9/29	20	6.0	0.13	0.010	0	0.009	20	0.09	0.13	110	140
C-703	1	9/26	21	6.0	0.07	0.010	0	0.013	16	0.12	0.17	110	150
C-694	1	9/26	21	7.0	0.07	0.010	0	0.024	16	0.10	0.09	110	150
	100	9/26	21	6.0	0.08	0.010	0	0.030	15	0.09	0.09	110	140
C-674	1	9/28	20	7.0	0.07	0.010	0	0.008	15	0.04	0.13	110	140
C-644	1	9/24	19	4.7	0.09	0.010	0	0.004	12	0.04	0.25	66	130
CSp-644	1	9/30	18	6.0	0.06	0.010	0	0.005	12	0.03	0.07	100	130
C-641	1	9/24	19	4.8	0.05	0.010	0	0.002	11	0.03	0.07	63	130
	250	9/24	19	4.3	0.14	0.020	0	0.010	12	0.07	0.10	57	140
C-615	1	9/23	18	5.5	0.06	0.010	0	0.002	10	0.04	0.00	40	130
C-597	1	9/23	21	4.1	0.08	0.010	0	0.033	11	0.01	0.12	51	120
	350	9/23	19	5.0	0.14	0.020	0	0.010	10	0.06	0.16	54	130

drilling and construction operations on the dam being built just above the mouth. However, the same condition was found to prevail at Range CPO-756, above the construction site and about 10 miles from the mouth. It has been reported that several base metal recovery mills on the Pend Oreille and other streams are discharging slimes which are the cause of much of this turbidity.

Temperature

In a large deep impoundment of this type it was suspected that some thermal stratification would be found. However, a careful examination throughout the lake showed no temperature stratification at any of the ranges established during this survey, at least at this season of the year. The largest temperature difference between surface and bottom was found at the 350-foot depth near Grand Coulee Dam. This differential reached a maximum of only 2°C at Range C-597, and generally varied from 0.5°C to 1°C at the other ranges, the temperatures being slightly lower in the deeper water than on the surface.

Seasonal temperature curves, obtained from the Bureau of Reclamation, show that little or no temperature stratification has been present in the reservoir during the last six years. The maximum temperature difference from surface to bottom has been from about 1 to 7°C, the decrease being rather uniform from top to bottom.

A typical seasonal temperature curve from the lake, furnished by the Bureau of Reclamation, is shown in figure 2. Maximum surface temperatures during 1951 were approximately 21°C and occurred in early September. Maximum bottom temperatures, occurring about a month later, were approximately 18°C. Maximum and minimum surface and depth temperatures occurring from 1943 to 1951, inclusive, are shown in table 5. From more detailed records it appears that a fairly definite temperature stratification did exist for the first few years after the lake was filled. The degree of stratification decreased until 1946. Since then it has followed a pattern similar to that shown in figure 2.

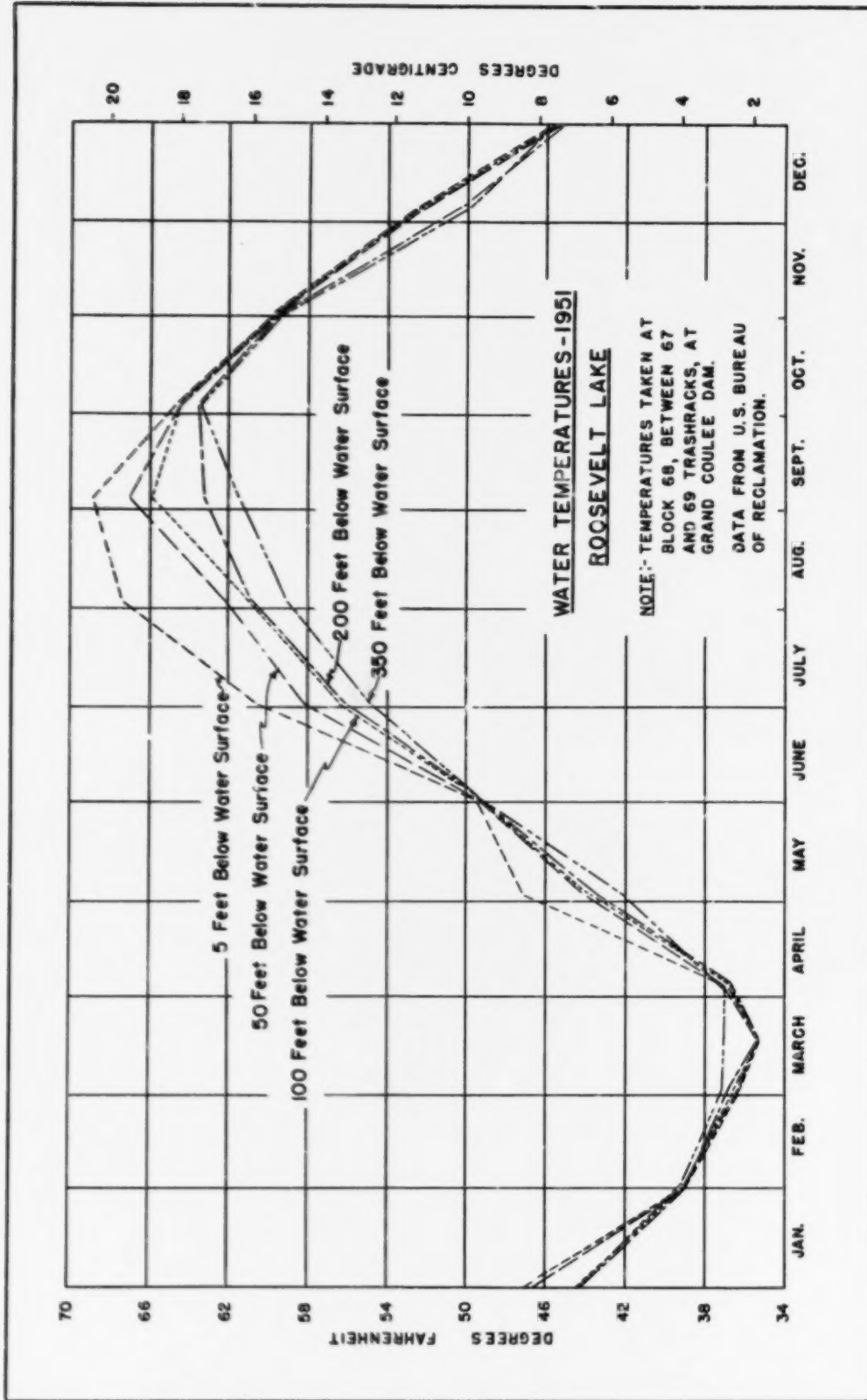


Figure 2

Table 5 - ANNUAL MAXIMUM AND MINIMUM TEMPERATURES -
ROOSEVELT LAKE NEAR GRAND COULEE DAM

Year	Depth in Feet	Maximum		Minimum	
		°C	Date	°C	Date
1943	5	20.6	Aug. 1	3.1	Mar. 15
	350	13.9	Nov. 15	3.1	Mar. 15
1944	5	21.7	Aug. 1	3.3	Mar. 15
	350	9.4	Jan. 1	3.3	Mar. 15
1945	5	19.7	Sept. 1	4.4	Apr. 1
	350	17.0	Dec. 1	4.4	Apr. 1
1946	5	19.4	Sept. 1	3.9	Mar. 15
	350	14.4	Nov. 1	3.9	Mar. 15
1947	5	19.4	Sept. 1	2.2	Mar. 1
	350	15.5	Oct. 1	3.3	Mar. 15
1948	5	21.4	Aug. 1	3.1	Mar. 15
	350	15.3	Sept. 1	3.1	Mar. 15
1949	5	22.8	Sept. 1	0.8	Feb. 1
	350	15.6	Oct. 1	2.8	Apr. 1
1950	5	20.6	Sept. 1	1.7	Mar. 15
	350	16.1	Oct. 1	2.2	Apr. 1
1951	5	20.4	Sept. 1	1.7	Mar. 15
	350	17.5	Oct. 1	2.8	Apr. 1

(Data from U.S. Bureau of Reclamation)

During this survey there was an increase of 3.5°C in surface water temperatures from Range C-732 (16.5°C) to Range C-597 (20°C). The increase was gradual throughout the impoundment. Results indicate either a warming within the reservoir or the entrance of colder tributary waters, which had not yet displaced the warmer water in the lower end of the lake. This could not be determined definitely without a temperature study at other seasons of the year, preferably when incoming tributary waters are at maximum summer temperatures.

The major cause for the lack of thermal stratification lies in the large flows entering the reservoir. Although the lake has a capacity of 10 million acre-feet, the annual average discharge is 80 million acre-feet, or enough to fill the lake 8 times within one year. The maximum discharge on record, in June 1948, was sufficient to fill the reservoir to capacity in 4 days. The large flows probably preclude any degree of either thermal or chemical stratification.

Dissolved Oxygen

Oxygen conditions were reasonably high and quite favorable for aquatic life throughout the entire body of the lake, both at the surface and in deep waters. Values ranged from a maximum of 8.8 p.p.m. at the surface to a minimum of 6.3 p.p.m. in the deepest portions near the dam. Values of 8 p.p.m. or more were usually found in waters less than 100 feet deep. The only areas sampled and found deficient in oxygen were in the Spokane River, where oxygen values as low as 3.1 p.p.m. were obtained near the bottom in waters 150 feet deep. Even in this area values for waters less than 100 feet in depth were fairly high.

In general, oxygen values throughout the lake were slightly below saturation. From the surface to 100 feet, results varied from 85 to 95% of

saturation; between 100 and 250 feet, from 75 to 85%; and between 250 feet and the deepest portions, from 65 to 75%. The deepest water sampled in the Spokane River was only 30 to 35% of saturation.

pH, Alkalinity, and Free CO₂

The pH values of surface samples ranged from 7.6 to 8.2, the lower results being found in the upstream section. There was a decrease in pH from the surface to the bottom due to the buildup of free CO₂ in the deeper waters. The maximum change in pH was found in the Spokane River (Range CSp-644), the values decreasing from 8.0 at the surface to 7.2 near the bottom. The same spread was found at Range C-597, values decreasing from 8.2 near the surface to 7.4 near the bottom.

Correspondingly, free CO₂ values ranged from 0 at the surface to a maximum of 6.0 p.p.m. at the 150-foot depth in the Spokane River (Range CSp-644). Near Grand Coulee Dam the variation was from 0 at the surface to 4 p.p.m. at 350 feet.

Methyl orange alkalinity generally ranged from 55 to 65 p.p.m. (as CaCO₃). No phenolphthalein alkalinity was found in any of the samples taken. The results were quite uniform at all sections, both at the surface and in the deep waters. A value of 80 p.p.m. was found in the Pend Oreille River, well above the backwater from Roosevelt Lake.

Mineral Analyses

The values for mineral analyses, given in table 4, do not indicate any detrimental condition existing in the lake. All of the results are within limits considered satisfactory for aquatic life. Values for iron, manganese, copper, and total solids are much higher in the Pend Oreille River than at any of the ranges within the lake. Total solids show a wide decrease from a high of 110 p.p.m. in the upper reservoir to a low of 40 to 50 p.p.m. at the

lower ranges, with a corresponding decrease in specific conductance. Sulfates also decrease from 20 to 10 p.p.m. from the upper to lower reaches. There appeared to be a slight increase of iron and manganese in the deeper waters. Other mineral characteristics showed some variation between ranges but no definite trends.

For the reservoir, results of mineral analyses (in parts per million) varied between: 18 and 21 for calcium; 4.1 and 7.0 for magnesium; 0.05 and 0.14 for iron; 0.01 and 0.02 for manganese; 0.002 and 0.033 for copper; 10 and 20 for sulfates; 0.01 and 0.12 for phosphates; 0.00 and 0.25 for nitrates; and 40 to 110 for total solids. Results for zinc were 0 p.p.m., while specific conductance values ranged from 120 to 150 micromhos per centimeter.

While the physical and chemical conditions within Roosevelt Lake appear favorable for the support of a good mixed aquatic fauna there is evidence of some changes in water quality characteristics, as has already been pointed out. The more important indications are that:

1. Although there is no evident thermal stratification within the lake, there appears to be a considerable warm-up of water from the upper to the lower parts of the impoundment. This should be studied more thoroughly over a longer period as the increased water temperatures may have considerable effect on the aquatic life in the river below the reservoir.
2. There is a minor decrease in the dissolved oxygen content, a slight build-up of free CO_2 , and some change in the pH between the surface and the bottom.
3. A decrease in the suspended material load, as well as total solids, occurs between the upper and lower sections.

4. A possible increase in iron and manganese occurs in the deeper lake waters.

BIOLOGICAL EXAMINATIONS

Physical and chemical conditions at all ranges within the lake area were favorable for the support of a good mixed aquatic biota, with the exception of the low oxygen content in the deeper areas of the Spokane River.

Plankton

Because of extreme fluctuations of plankton organisms at different seasons and under different water conditions, a study of the plankton at any one season can give only an approximate indication of the productivity of a body of water. It was surprising to note the relatively extreme scarcity of phytoplankton throughout the lake at a season of the year and under water conditions normally favorable to such organisms. Table 6 shows the number of organisms present and the weight of plankton and organic material at the various ranges.

Phytoplankton were extremely limited at the upper ranges, with only a slight increase toward the lower part of the lake. The diatom Fragilaria sp was the predominant form in most of the samples. At several of the ranges near the entrance of tributary streams fair numbers of single-celled green algal forms were present. Samples from the Spokane River, Range CSp-644, contained much larger numbers of phytoplankton, consisting mostly of the diatom Cyclotella sp, a form found abundantly in some of the tributary streams in the Priest Rapids - Paterson section of the Columbia River. Many other diatoms as well as some green and blue-green algal forms were present at this range. The numbers of phytoplankton in the lake were generally lower than had been found in the Priest Rapids - Paterson section.

Table 6 - PLANKTON - COLUMBIA RIVER - ROOSEVELT LAKE SURVEY

SAMPLING DATA				Plankton Weight		Plankton Count - Average Number of Organisms																						
Sampling Range	Location of Sample	Depth - Feet	Date of Sample	Net Weight per Liter Milligrams	Organic Matter per Liter Milligrams	Per Milliliter																						
						MACILLANOPHYCEAE - TOTAL	Asterionella sp.	Cyclotella sp.	Diatom sp.	Fragdiaria sp.	Cocconeis sp.	Melosira sp.	Navicula sp.	Stenella sp.	Tabellaria sp.	CHLOROPHYCEAE - TOTAL	Achnanthes sp.	Fragdiaria sp.	Scenedesmus sp.	Retrophegaceae - TOTAL	Opallidophyta sp.	Pigmented Flagellates - TOTAL	PROTOZOA - TOTAL	CRUSTACEA - TOTAL	Copepoda	ROTIFERA - TOTAL	MISCELLANEOUS	TOTAL ORGANISMS PER MILLILITER
C-760	W. Shore	0	9/29			16	2			8				1	3	1								1			1	17
C-732	Cross-section	0	9/29			10	1		1	4				1	1	1							2				1	11
C-703	"	0	9/27			13	3			5		1		1	2	5			3			11					7	16
C-694	"	0	9/26	1.09	0.31	21	5			11		1	1		2	45			36			86					6	66
C-674	Depth	100				18	3			10		1	1		4	1						2					1	20
C-674	Cross-section	0	9/28			686				17			669			17			6			1					1	703
C-644	"	0	9/24			72				69		1				50						4					6	122
C-644	"	0	9/24			2,091	49	1,665	7	10	12					54			22			3				14	1	2,209
C-643	"	0	9/24	2.50	0.52	19	1			17						2						17					1	21
C-615	Depth	200				16				11			3			2			1			3					1	19
C-615	Cross-section	0	9/23			63				61						1			1			64					1	64
C-597	Depth	100				50				48						1						15					2	51
C-597	Cross-section	0	9/25	1.14	0.35	33	1			29						2			1			69					15	35
C-597	Depth	300				6	1			3						1						4					1	7

Zooplankton, consisting of protozoans, rotifers, and crustaceans, were noticeably more abundant in Roosevelt Lake than in the lower sections of the Columbia River. Large swarms of micro-crustaceans, both cladocerans and copepods, were observed in lower parts of the lake, from Range C-644 to Grand Coulee Dam. These organisms were quite plentiful near the shores and large numbers could readily be collected in tow nets. Their true number is probably not shown in the quantitative results, as composite samples were taken at $1/4$, $1/2$, and $3/4$ points and would not include the large numbers observed in shore areas.

An examination of the plankton tows taken at the various ranges, while not quantitative, does give an indication of relative numbers of the various organisms of this type. A sample from Range C-732 shows an extremely sparse population, consisting almost entirely of *Fragilaria*. At Range C-703, larger numbers of diatoms were present along with a few single-celled green algae and a few protozoans. No crustaceans were observed. At Range C-674, *Fragilaria* was the predominant photoplankton form. A fair number of crustaceans, mostly copepods, along with a few protozoans and rotifers were also present. At Range C-644 *Fragilaria* and some green algal forms were fairly abundant and copepods were numerous. A few protozoans and rotifers were also found. In the Spokane River, diatoms and green algae were quite abundant and practically no zooplankton forms were present. At Ranges C-615 and C-597, crustaceans, mostly cladocerans, were very abundant, making up by far the largest proportion of the plankton. *Fragilaria*, a few green algae, rotifers and protozoans were also collected.

In general, plankton samples taken in deeper water contained fewer organisms than those from the surface. Nevertheless some organisms, both phytoplankton and zooplankton, were found to be present at all depths down to

350 feet, the numbers decreasing as the depth increased.

The plankton would be considered extremely poor, especially in the upper sections of the lake. It would be quite important to study the plankton at other seasons of the year to see if this condition prevailed at all times. One of the reasons for a study of the plankton in this lake was to determine whether build-ups, which could affect water treatment plants in downstream sections of the Columbia River, might occur. At this season there was definitely no great build-up of phytoplankton forms, although zooplankton was relatively abundant in the lower lake. Large increases in the diatom Asterionella sp were observed in the lower Columbia River in May and June during the years 1950, 1951, and 1952. A study of the plankton in the lake during or prior to this period would be quite important to determine if a build-up here may be related to the downstream pulses. Studies at other seasons may also be important in determining the lake productivity.

Bottom Fauna

The numbers and weights of bottom animals in the quantitative collections made at the various ranges are shown in table 7.

Bottom animal populations were quite poor throughout the lake, practically the entire fauna consisting of two organisms, Oligochaete worms and Chironomid larvae. The variation in numbers and weights was very great, even at the same station, the numbers ranging from 26 to 840 per square foot. This variation was, no doubt, caused by the differences in bottom conditions. Where large quantities of silt were brought up with the samples there were a great many more organisms present than when fine and coarse sand was the only bottom material.

No definite relationship between bottom fauna in upper and lower areas of the lake could be established as fairly rich and poor samples were

Table 7 - BOTTOM FAUNA, COLUMBIA RIVER

SAMPLING DATA				ORGANISMS					TOTAL ORGANISMS	TOTAL PER SQUARE FOOT
Sampling Range	Distance from South or East Shore	Number of Samples & Depth Taken	Date of Sample (1952)	Size of Sample and Method of Collection	Oligochaetae	Diptera: Chironomidae (Widgefly Larvae)	Tupidiidae (Cranefly Larvae)	Trichoptera: (Caddisfly Larvae)		
C-732	3/4	1 @ 12'	9/29	0.5 Sq. Ft. Ekman	Number	13			13	26
					Weight				.01	.02
C-703	1/4	1 @ 80'	9/28	0.25 Sq. Ft. Ekman	Number	30			30	120
					Weight	.09			.09	.36
C-694	1/4	1 @ 90'	9/26	0.5 Sq. Ft. Ekman	Number	97	9		106	212
					Weight	.15	.02		.17	.34
	3/4	1 @ 100'		"	Number	420			420	840
					Weight	1.28			1.28	2.56
C-674	1/4	1 @ 70'	9/28	"	Number	10	2	1	13	26
					Weight				.01	.02
	3/4	1 @ 170'		"	Number	25	11		36	72
					Weight	.08	.03		.11	.22
C89-644	1/2	1 @ 110'	9/30	"	Number	64			64	128
					Weight	.05			.05	.10
	1/4	1 @ 85'	9/30	"	Number	12			12	24
					Weight		.01		.01	.02
C-641	1/2	1 @ 270'		"	Number	215			274	548
					Weight	.58	.10		.68	1.36
	3/4	1 @ 150'		"	Number	9	48		57	114
					Weight	.02	.07		.09	.18
C-615	1/4	1 @ 165'	9/23	"	Number	25	9		25	50
					Weight	.07	.02		.07	.14
	0	1 @ 90'		"	Number	2	12		14	28
					Weight		.02		.02	.04
C-597	1/4	1 @ 385'	10/1	"	Number	43	36		79	158
					Weight	.15	.06		.21	.42
	3/4	1 @ 115'		"	Number	1	37		38	76
					Weight		.05		.05	.10

obtained in the same areas. Bottom fauna did appear just as abundant, if not more so, in the deeper waters as in the shallower regions. A visual examination of shallow shore areas (or littoral zones) did not disclose the presence of any more, if as many, animals as were present in the deep water. The winter drawdown of 50 to 80 feet is probably responsible for the scarcity of animals in the littoral zone. Bottom animals are normally most abundant in the shallow areas, but the large annual drawdowns would tend to destroy these and not give them a chance to become well-established.

Observed physical conditions throughout the lake are not too favorable for the development of a rich bottom fauna. Fine and coarse sand covers a major portion of the lake bed, but there are some areas, mostly in coves and near the shoreline, which have fair silt deposits. The bottom fauna appear much richer at or near such deposits. Much of the bottom is covered with a layer of debris consisting mostly of wood fibers. The large amounts of water containing suspended material which flows into and through this reservoir during the spring floods probably causes an annual deposition of sand, particularly in the upper lake. This would have a smothering effect on bottom animals and tend to discourage their establishment.

The bottom fauna population in Roosevelt Lake is entirely different from the populations generally occurring in the Columbia River. The more abundant forms found in other parts of the stream, mayfly and stonefly nymphs, caddis larvae and mollusks, were not found to any extent in the lake.

The scarcity of bottom animals and the limitation of those present to the quite tolerant forms, the scarcity of mollusks, the very poor phytoplankton flora, and the scarcity of zooplankton in the upper reservoir would indicate that conditions unfavorable to the development of these organisms must be present at times. While no detrimental chemical conditions were found during

this survey, it is felt that this problem should be further investigated.

As most of the waters entering the reservoir originate in areas of extensive mining operations, toxicity from heavy metals, such as copper, lead, or zinc, could certainly be possible. Bottom organisms would probably be the first affected by pollution of this kind. The large amounts of suspended material in the Pend Oreille River would be expected to be detrimental to aquatic life in that stream.

Fish

Juvenile fish collections were limited to Ranges C-694 and C-597. The species found consisted of shiners (Richardsonius balteatus), chubs (Mylocheilus caurinus), suckers (Catostomus macrocheilus), and squawfish (Ptychocheilus oregonensis), the degree of abundance in the collections being about in the order named. These fish were taken only in shoal areas, where large schools were easily visible. No effort was made to obtain extensive collections in different types of habitat and consequently the samples taken show only some of the more abundant species. Visual observations throughout many parts of the lake, however, did indicate a relatively sparse juvenile fish population, as compared to the Priest Rapids - Paterson section of the Columbia River. The National Park Service reported the collection of a small number of smallmouth bass, (Micropterus dolomieu), in some collections from sloughs in the vicinity of the Kettle Falls Ranger Station. No doubt many other species of juvenile such as sculpins, dace, chiselmouth, and carp are present but were not observed during this survey.

Gill netting for adult fish was also confined to Ranges C-694 and C-597. The record of gill-net catches is shown in table 8. Each date represents one over-night bottom set with a net made up of 25 yards of 1-inch mesh and 50 yards each of 2-inch and 3-inch mesh. While the results of the limited gill-

Table 8 - GILL-NET SETS, ROOSEVELT LAKE

Sampling Range	Date (1952)	Location of Sets	Depth of Set - Feet	Species Caught	Number of Each Species	Range of Sizes (Inches)	Range of Weights (Ounces)
C-694	9/27	At East Shore, near confluence of Colville River	10 to 30	Sucker, <i>Catostomus macrocheilus</i>	2	18	24 - 32
				Whitefish, <i>Prosopium</i> sp.	1	17	32
				"	1	10	6
	9/28	At 1/4 distance from East Shore	15 to 50	Whitefish, <i>Prosopium</i> sp.	1	10	6
				Squawfish, <i>Pygocentrus oregonensis</i>	7	10 - 14	8 - 16
				Sucker, <i>Catostomus macrocheilus</i>	2	15 - 18	20 - 36
	9/29	At 1/2 distance from East Shore	125	Whitefish, <i>Prosopium</i> sp.	3	16	24 - 30
				Sucker, <i>Catostomus macrocheilus</i>	1	15	20
				"			
	9/30	At West Shore across entrance of Sherman Creek	20 to 80	Chub, <i>Mylocheilus caurinus</i>	7	9 - 11	6 - 10
				Squawfish, <i>Pygocentrus oregonensis</i>	5	10 - 12	8 - 12
				"	1	18	32
C-597	9/25	At South Shore, near Warehouse Canyon. From Shore extending into Lake	5 to 35	Sucker, <i>Catostomus macrocheilus</i>	1	15	18
				Tench, <i>Linna tinea</i>	1	14	30
				Yellow Perch, <i>Perca flavescens</i>	4	7 - 9	4 - 6
	10/1	Across Warehouse Canyon, before entrance into Lake	5 to 30	Trout, Dolly Varden, <i>Salvelinus malin</i>	1	12	16
				Chub, <i>Mylocheilus caurinus</i>	41	8 - 11	6 - 10
				Squawfish, <i>Pygocentrus oregonensis</i>	11	8 - 12	8 - 12
				Chub, <i>Mylocheilus caurinus</i>	3	11	6 - 10
				Squawfish, <i>Pygocentrus oregonensis</i>	5	18 - 20	30 - 44
				"	5	10 - 12	8 - 12
				Tench, <i>Linna tinea</i>	1	13	24

netting done could not be considered conclusive, a preponderance of undesirable and forage species is indicated. This condition is further borne out from reports of very poor takes of game and food species by fishermen.

The total catch at Range C-597 consisted of undesirable and forage species. All sets at Range C-694 contained one or more food and game species but in fewer numbers than undesirable and forage species. Squawfish and chubs made up by far the largest proportion of the catch, squawfish being taken in the greatest number of sets and chubs in the greatest numerical abundance. Suckers were less prevalent numerically, but were caught in all sets at Range C-694. Whitefish were the most abundant of the desirable species, several individuals being taken in all main channel sets at this cross-section.

The gill-net catch here is comparable to several previous catches in the Priest Rapids - Paterson section of the Columbia River with similar nets. A preponderance of rough fish was also found in the downstream area. Chubs, however, were much more numerous in the Roosevelt Lake catches than in those in the lower section. Suckers were the most predominant fish in the downstream catches. Squawfish were equally prominent in both areas. A few more food and game fish, mostly smallmouth bass and blueback salmon, were generally found in the lower area catches.

Also of interest in the Roosevelt Lake fish was the extreme tapeworm parasitism observed in the chubs. Practically all specimens caught contained large tapeworms in their body cavities. In some specimens the sides of the fish were greatly distended and the body cavity completely full of the parasites. It is not known how widespread this parasitism is or to what extent it occurs in other fish. Extreme parasitism of this kind may have considerable effect on fish reproduction, and could well be considered for further investigation.

Other species of fish were observed or reported caught by fishermen in Roosevelt Lake. Among those seen during this survey were carp (Cyprinus carpio), and ling (Lota lota). Some carp were observed in nearly all sections. These fish are reported as being very abundant in some areas of the reservoir, especially near the mouth of the Kettle River, and are particularly noticeable in sloughs during the spring, when they congregate in large schools near shoal areas for spawning. From the limited observations, however, this species appears no more abundantly in the lake than in other sections of the river. In the Priest Rapids - Paterson section large schools may be seen in practically every slough and also in many parts of the main stream. The only sample of ling seen was a large specimen washed ashore. This species is reported occasionally caught by fishermen in the lake.

Reports from the National Park Service and from fishermen in the area indicate sport fishing in Roosevelt Lake has been notably poor since the completion of Grand Coulee Dam in 1939. Prior to that time some migratory species, principally steelhead (Salmo gairdnerii) and chinook salmon (Oncorhynchus tshawytscha), were caught in the river. The establishment of the dam, however, cut off the migratory runs as the dam was too high for fish passage. Evidently the void created here was filled by rough fish, undesirable from the standpoint of sports fishermen. Little effort has been made since to establish more desirable species. Probably the most desirable species now caught are a limited number of Kamloops rainbow trout (Salmo gairdnerii kamloops) and an occasional Kakanee (Oncorhynchus nerka kennerlyi), a species native to the upper Columbia River system. Trout, including native rainbows (Salmo gairdnerii), brook (Salvelinus fontinalis), cutthroat (Salmo clarkii), and Dolly Varden (Salvelinus malma) are occasionally taken in the reservoir and are fairly abundant in some of the tributary streams.

Some fishing for smallmouth (Micropterus dolomieu) and largemouth (Micropterus salmoides) bass is said to exist seasonally in the lower Kettle River and in a few other areas of Roosevelt Lake.

From the biological standpoint Roosevelt Lake would be considered quite poor because:

1. The incoming waters, draining mostly mountain regions, contain little or no nutrient material for aquatic organisms.
2. Large amounts of suspended materials are added by incoming flows, especially during the annual spring floods, and are deposited on the lake bottom.
3. The ratio of incoming water to reservoir capacity is at times quite large, causing frequent replacement of the contents at certain seasons of the year.
4. The shores drop off sharply, giving very few shallow areas and consequently little aquatic vegetation.
5. The large winter drawdown interferes with the establishment of bottom organisms and creates conditions unfavorable for the natural reproduction of many species of fish.

RADIOLOGICAL STUDIES

Although it was not intended to make radiological studies at the time the Roosevelt Lake Survey was done, it was later decided to determine background or long-life radioactivities of fish and plankton. The samples were collected in September 1952 and the examinations made in February 1953. The results are presented in table 9.

The corrected counts were generally at or below the minimum detectable

limits, as determined by the 95% confidence levels.⁽¹⁾ The results were so close to instrument background that they were considered not significantly different from "zero" counts. Samples were counted in both the internal flow and end-window tube counters, for 32 and 15 minutes, respectively.

(1) Jarrett, Alan A., "Statistical Methods Used in the Measurement of Radioactivity - Some Useful Graphs". MonP-126, Contract No. W-35-058. Eng. 71. U.S. Atomic Energy Commission, June 17, 1946.

Table 9 - RESULTS OF RADIOACTIVITY COUNTING FOR FISH AND PLANKTON - ROOSEVELT LAKE

Type of Sample	Beta Activity		Alpha Activity		Type of Sample	Beta Activity		Alpha Activity	
	Counts/min. (Corr. for background)	$10^{-7} \pm \mu\text{Ci/gm}$	Counts/min. (Corr. for background)	$10^{-7} \pm \mu\text{Ci/gm}$		Counts/min. (Corr. for background)	$10^{-7} \pm \mu\text{Ci/gm}$	Counts/min. (Corr. for background)	$10^{-7} \pm \mu\text{Ci/gm}$
Plankton	2.6 $\pm$ 2.6 -0.3 $\pm$ 2.3 1.4 $\pm$ 2.6 0.3 $\pm$ 2.5 -0.8 $\pm$ 2.4 -2.0 $\pm$ 2.5	190 $\pm$ 190 < 430 < 250 < 190 < 530 < 170	-0.10 $\pm$ 0.10 0.06 $\pm$ 0.17 -0.13 $\pm$ 0.05 0.22 $\pm$ 0.21	< 9 - < 22 < 5 19 $\pm$ 18	Chub (Juv.)	0.7 $\pm$ 2.4 -0.2 $\pm$ 2.5 2.2 $\pm$ 2.5 0.6 $\pm$ 2.5 1.4 $\pm$ 2.4 3.4 $\pm$ 2.5	< 11 < 8 < 13 < 12 < 13 16 $\pm$ 12	0.01 $\pm$ 0.11 0.23 $\pm$ 0.20 0.14 $\pm$ 0.17	< 0.5 1.6 $\pm$ 1.4 < 1.2
Shiners (Juv.)	3.2 $\pm$ 2.6 -1.1 $\pm$ 2.5 -0.7 $\pm$ 2.4 -1.4 $\pm$ 2.5 1.8 $\pm$ 2.5	18 $\pm$ 15 < 17 < 17 < 15 < 29	0.09 $\pm$ 0.17 0.21 $\pm$ 0.20	< 1.6 1.7 $\pm$ 1.6	Chub - Bone	-0.7 $\pm$ 2.3 -2.1 $\pm$ 2.5 0.3 $\pm$ 2.3 -2.2 $\pm$ 2.4	< 61 < 40 < 45 < 32	0.05 $\pm$ 0.14 0.01 $\pm$ 0.12	< 3.0 < 2.1
Squawfish (Juv.)	1.9 $\pm$ 2.6 0.3 $\pm$ 2.4 -0.4 $\pm$ 2.5 -0.1 $\pm$ 2.4 2.8 $\pm$ 2.6	< 18 < 16 < 13 < 14 25 $\pm$ 23	-0.04 $\pm$ 0.11 0.19 $\pm$ 0.19 0.08 $\pm$ 0.15	< 1.1 1.4 $\pm$ 1.4 < 1.9	Whitefish - Muscle	0.5 $\pm$ 2.3 -2.5 $\pm$ 2.4	< 11 < 15	0.05 $\pm$ 0.14	< 1.2
	-1.1 $\pm$ 2.3 -1.9 $\pm$ 2.5	< 16 < 13	0.23 $\pm$ 0.20	1.7 $\pm$ 1.4	Whitefish - Liver	1.5 $\pm$ 2.5 -0.2 $\pm$ 2.4	< 10 < 12	0.11 $\pm$ 0.17	< 1.2
	2.0 $\pm$ 2.5 -2.7 $\pm$ 2.4 1.3 $\pm$ 2.4 -0.4 $\pm$ 2.5 1.3 $\pm$ 2.5 -0.8 $\pm$ 2.5	< 34 < 24 < 20 < 20 < 28 < 19	-0.04 $\pm$ 0.11 -0.01 $\pm$ 0.12 -0.07 $\pm$ 0.11	< 1.5 < 1.4 < 1.2	Whitefish - Bone	-0.1 $\pm$ 2.3 1.3 $\pm$ 2.5	< 29 < 22	0.11 $\pm$ 0.17	< 2.0
	0.2 $\pm$ 2.5 -0.8 $\pm$ 2.5 0.7 $\pm$ 2.4 -2.4 $\pm$ 2.5 1.1 $\pm$ 2.5 -0.7 $\pm$ 2.5	< 13 < 14 < 15 < 13 < 22 < 27	0.0 $\pm$ 0.14 0.03 $\pm$ 0.15 -0.13 $\pm$ 0.01	< 1.1 < 1.1 < 0.2	Sucker - Muscle	1.1 $\pm$ 2.4 0.0 $\pm$ 2.5	< 12 < 43	0.11 $\pm$ 0.17	< 1.3
					Sucker - Liver	-1.4 $\pm$ 2.3 2.4 $\pm$ 2.5	< 16 < 24	0.01 $\pm$ 0.12	< 1.7
Suckers (Juv.)					Sucker - Bone	-0.5 $\pm$ 2.3 1.3 $\pm$ 2.5	< 26 < 19	0.17 $\pm$ 0.18	< 1.9

SUPPLEMENTAL STUDIES

In order to determine certain characteristics of Roosevelt Lake at very low water levels, additional studies were made and samples collected on April 13 and 14, 1953. The reservoir was at the lowest point of drawdown for the year. Water level elevation was at 1,236 feet above mean sea level, 54 feet below the normal pool elevation of 1,290 feet above mean sea level.

OVERALL PROGRAM

Efforts were devoted principally to:

1. Bacteriological examinations to determine the extent of seepage through the Crescent Bay fill and the possible contamination near the irrigation water pump intake at the Dam, as well as any possible contamination in other parts of the lake during the extreme low water stages.
2. Mineral examinations to determine possible toxicity to aquatic organisms from heavy metals.
3. Visual observations to determine the extent of penetrations of finely suspended material from mine wastes into the reservoir at the very low water stages.
4. Plankton examinations to determine the possible build-up of any plankton

organisms within the reservoir which may affect downstream water supplies or other water quality characteristics.

5. Added determinations of background radioactivity levels within the reservoir.

Water samples for M.P.N. Coliform organisms were taken at Ranges C-732, C-694, CSp-644, and C-597. The laboratory work was done by State Pollution Control Commission personnel at the City Health Department Laboratories in Spokane.

Physical and chemical examinations were made in the field on water samples from these same stations for temperature, turbidity, dissolved oxygen, pH, and methyl orange alkalinity. Composite surface samples for mineral determinations were taken at Ranges C-694 and C-732. Composite surface samples, varying from 2 to 6 liters, were taken at Ranges C-732, C-694, and C-597 for quantitative estimation of the number of plankton organisms. A few samples of plankton, algae, and juvenile fish were collected for background radioactivity determinations.

DISCUSSION OF RESULTS

The results for the supplemental studies in general confirm the findings of the previous work. The various aspects are discussed below.

Bacteriological Examinations

Highest values, 230 M.P.N. per 100 milliliters, were found at Range C-732, at Northport. This was less than the results of last September, when highest values were found at this range. At midstream on Range C-694 a high value of 230 M.P.N. per 100 milliliter was also found, other results across this range reaching a maximum of 60 M.P.N. per 100 milliliters. Results at Range C-597, near Grand Coulee Dam were all less than 45 M.P.N. per 100 milliliters,

indicating no seepage through the fill separating Crescent Bay and Roosevelt Lake.

The results of the bacteriological examinations are given in table 10, below.

Table 10 - BACTERIOLOGICAL ANALYSES, SUPPLEMENTAL STUDIES

Sampling Range	Distance from South or E. Shore	Date (1953)	MPN per 100 ml.	Sampling Range	Distance From South or E. Shore	Date (1953)	MPN per 100 ml.
C-732	E. Shore	4/14	230	C-597	Bel.Cres. Bay Fill	4/13	< 45
C-694	E. Shore	4/14	< 45		Pump Pl. Intake		< 45
	1/4		< 45		1/2		< 45
	1/2		230		3/4		< 45
	3/4		< 45				
CSp-644	1/2	4/13	60				

Physical and Chemical Examinations

Turbidity in the river above the present backwater and in the upper part of the reservoir was somewhat higher than previously. This turbidity was caused by the flour-like material observed in the earlier study. The extent of penetration of this material into the reservoir was much further than at the higher water stages, extending at this time to beyond the mouth of the Colville River, Range C-694. Deposits of this material were visible in the areas exposed by the drawdown for approximately 20 miles below Northport. A slight turbidity and greenish cast observed in the lower reservoir was in all probability due to phytoplankton.

Water temperatures were, of course, much lower during this late winter period than in the previous survey, with the tributaries somewhat warmer than the lake proper. No thermal stratification was indicated in the deeper waters. The pH values were somewhat less in the lower reservoir than previously. Dissolved oxygen values were at or near saturation. The results are presented

in table 11, below.

Table 11 - ANALYTICAL RESULTS, SUPPLEMENTAL STUDIES

Sampling Range	Distance From South or E. Shore	Depth Ft.	Date (1953)	Turb. ppm	Temp. °C	D.O. ppm	pH	M.O. Alk. ppm
C-732	10'	1	4/14	26	6.5	-	7.6	72
C-694	1/2	1	4/14	13	6.5	10.8	7.6	70
CSp-644	1/2	1	4/13	-	9.5	9.8	7.2	48
C-597	1/2	1	4/13	7	5.5	10.2	7.7	65
	1/2	200		-	5.5	10.8	-	-

Mineral analyses of water samples taken in the upper reservoir showed little change from previously determined conditions. Although values for zinc were somewhat higher, values for heavy metals were below those generally considered toxic to aquatic organisms. The laboratory results are shown in table 12.

Table 12 - MINERAL ANALYSES, SUPPLEMENTAL STUDIES

	Range C-732		Range C-694
	Unfiltered	Filtered	Unfiltered
Date	4/14/53	4/14/53	4/14/53
Depth	1'	1'	1'
Ca-ppm	-	-	21
Mg	4.5	-	4.8
Fe	0.10	-	0.07
Mn	0.04	0.04	0.27
Zn	0.075	0.033	0.01
Cu	0.023	0.022	0.010
SO ₄	-	-	17
PO ₄	0.07	-	0.05
NO ₃	0.24	-	0.32
Tot. Sol.	120	-	110
Na	-	-	1.8
Si	-	-	9.3
Cl	0.21	-	0.18
Pb	0.025	-	0.026
Spec. Cond. μ mhos/cm	98	-	93

Biological Examinations

Biological examinations during this brief survey were confined primarily to a numerical estimation of plankton. Phytoplankton populations were much higher than found in the fall survey, especially in the lower part of the reservoir where a quite heavy pulse of the diatom Asterionella sp was found to occur. This no doubt adds to the increase in this form previously found abundant in the Priest Rapids - Paterson Section of the Columbia River during May and June. It may also have some effect on the clogging of water supply filters, reported downstream from the reservoir. Concentrations of this organism also produced a noticeably fishy odor. The heavy pulse of crustaceans in Lower Roosevelt Lake, observed last fall, was not evident at this time. Plankton results are shown in table 13.

Table 13 - PLANKTON RESULTS, SUPPLEMENTAL STUDIES

	Range C-732	Range C-694	Range C-597	
Date of Sample (1953)	4/14	4/14	4/13	4/13
Location of Sample	E. Shore	Cross-Sect.	Cross-Sect.	Cross-Sect.
ORGANISMS PER MILLILITER				
BACILLARIOPHYCEAE - TOTAL	166	274	1,006	969
<u>Asterionella</u> <u>sp</u>	140	215	898	839
<u>Cyclotella</u> <u>sp</u>	-	3	20	10
<u>Fragillaria</u> <u>sp</u>	2	3	7	5
<u>Melosira</u> <u>sp</u>	-	-	2	10
<u>Navicula</u> <u>sp</u>	-	6	-	2
<u>Synedra</u> <u>sp</u>	3	2	25	20
<u>Tabellaria</u> <u>sp</u>	15	24	42	66
CHLOROPHYCEAE - TOTAL	1	3	111	83
<u>Ankistrodesmus</u> <u>sp</u>	-	3	96	76
PIGMENTED FLAGELLATES - TOTAL	-	1	7	42
ORGANISMS PER 200 MILLILITERS				
PROTOZOA - TOTAL	6	2	2	3
FILAMENTOUS BACTERIA AND FUNGI - TOTAL	2	-	-	-
ROTIFERA - TOTAL	2	-	2	7
MISCELLANEOUS	4	16	11	6
TOTAL ORGANISMS PER MILLILITER	167	278	1,124	1,094

A superficial examination of riffle areas near Northport, covered with approximately 20 feet of water at normal reservoir levels, indicated a very poor bottom fauna. Heavy deposits of rock flour were noted on rocks in this area.

Observation of the exposed areas and mud flats in the drawdown areas showed an absence of vegetation. Quite large areas of these exposed mud flats exist at intervals in the upper reservoir from below Northport near Gifford Ferry, with a few such smaller areas in the lower reservoir.

Radiological Examinations

Water and biological samples were collected at Ranges C-694 and C-597 and examined for radioactivity within a week after collection. A total of six samples were used for this purpose, two of water, two of plankton, one of algae, and one of juvenile fish.

In general, activities were all at or below the background level. One plankton portion, collected at Range C-597, near Grand Coulee Dam, showed a noticeable amount of alpha activity but such activity was not found in any other portions of the same or similar samples. It is possible that the activity may have been due to some particulate matter derived from uranium mining operations reported some 40 miles upstream from Grand Coulee Dam.